

Qualification & Reliability of Photonic Devices System Perspective

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NEPP Electronics Technology Workshop (ETW 2018)

June 17-20, 2019

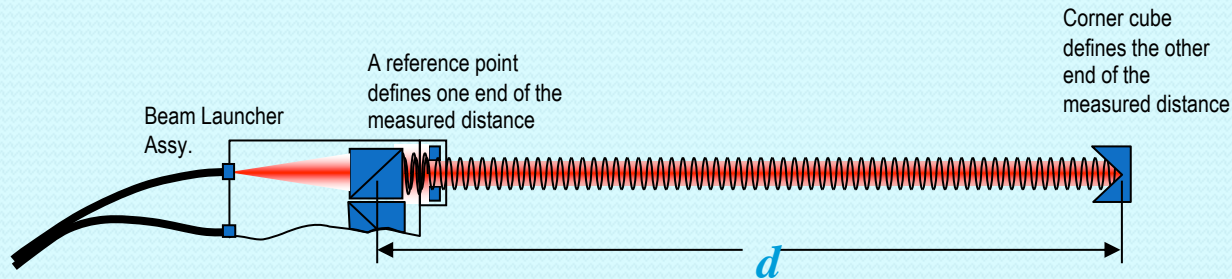
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Introduction

- This talk concentrates on photonics devices of a system that JPL is in the process of qualifying
- Unlike electronics parts, standard guidelines for qualification and screening of photonics parts for space application does not exist
- JPL had to develop process for qualify and screening of these photonics parts
- The system is a metrology system capable of measuring displacement with nms accuracy
- This talk focuses only on the photonics part of the system

System Overview Concept



- A Laser Metrology System is a “yardstick,” with “nm-marks” provided by the interference fringes of the laser beam
 - Changes in the distance d between the Beam Launcher (BL) and the Corner Cube (target) are measured as phase shifts between input and output beams
 - Uses heterodyne techniques to measure phase
 - “count fringes” corresponds to the changes in d
- It can be used for alignment and wavefront control of the future NASA segmented telescope such as Luvior or HabEx



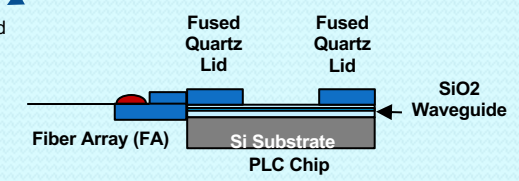
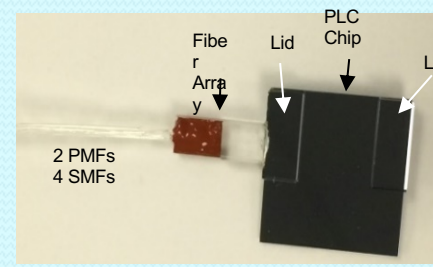
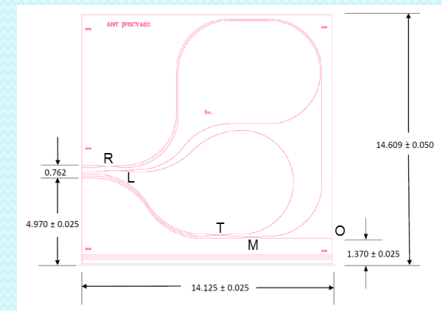
Type of photonics devices

- Two type of photonics devices
 - Passive
 - Buy COTS and put them through environmental requirements
 - 6 thermal cycles
 - Radiation
 - Active
 - Screening and lot qualification using Telcordia and Mil-STD combine

Passive Devices (1/2)

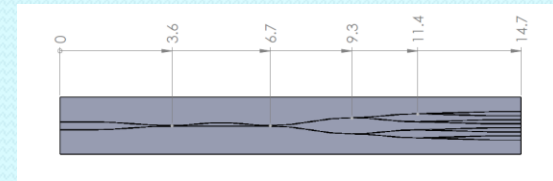
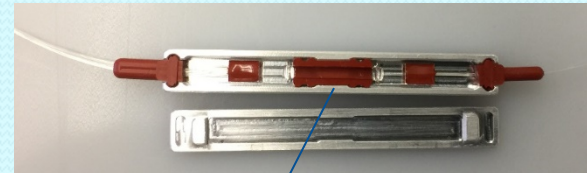
• Waveguide

- Custom made interferometer integrated photonics on a silicon chip
- Perform full Qualification on 3 units
 - Performance
 - Dynamic test
 - Radiation
- Screening other devices after qualification
 - Performance
 - Thermal cycle
 - Dynamic test



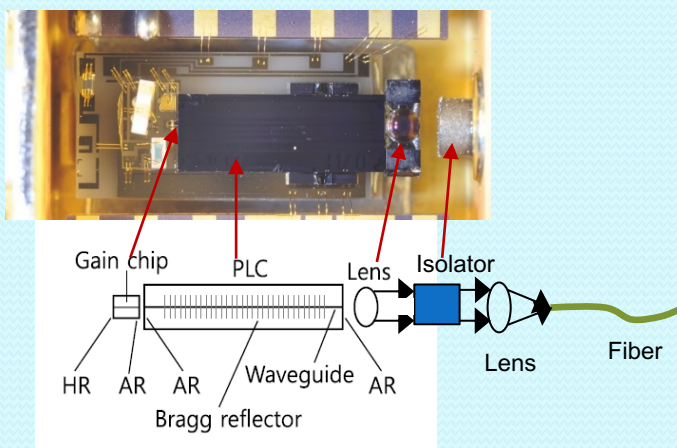
Passive Devices (2/2)

- Splitters 1x2 and 2x8
 - Planar Lightwave Circuits (PLC)
 - Screening
 - Performance (PER, IL, uniformity)
 - Thermal cycle
- Fiber optics
 - Single mode (SM)
 - Polarization maintain fiber (PM)
 - Polarizing fiber (PZ)
 - There are plentiful data on most fibers
 - Perform lot qualification



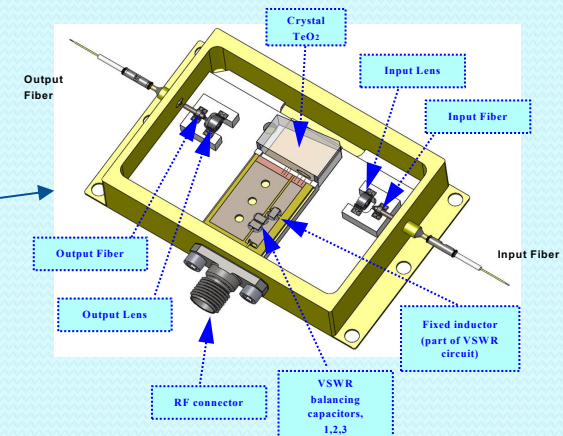
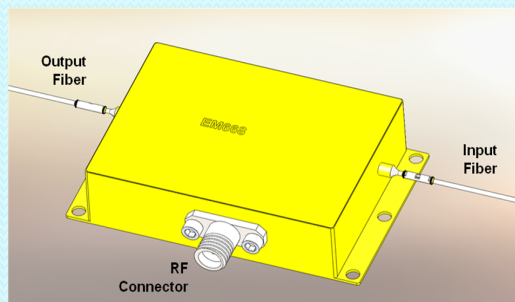
Active Devices (1/2)

- Laser- 1.5 μm external grating semiconductor laser with narrow linewidth
 - COTS laser, with screening and lot qualification
 - Guidelines developed at JPL for screening and qualification
 - 21 lasers were used for lot qualifications



Active Devices (2/2)

- Acousto-Optic Modulator (AOM)- provide frequency shift to the laser light
 - Custom made, with screening and lot qualification
 - Guidelines developed at JPL for screening and qualification
 - 10 AOMs were used for lot qualification





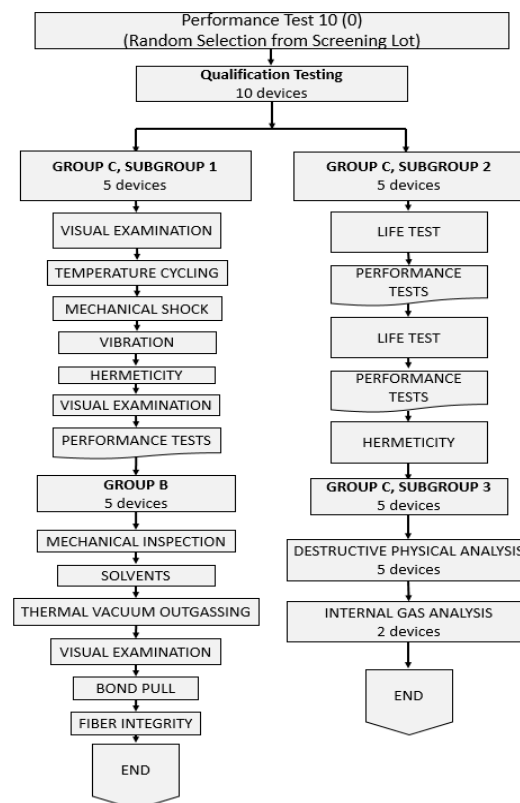
Current Qualification Process (1/2)

- JPL developed qualification process using Mil-STD and Telcordia

Qualification Steps for Laser

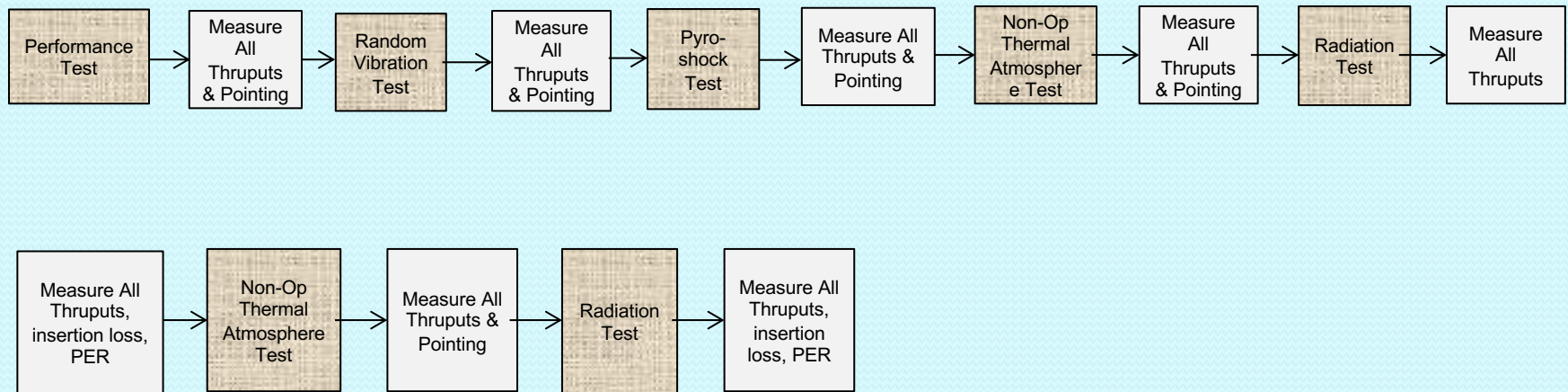
Qualification Step Number	Test	Method	Conditions	Quantity Accept (Failure No.)
Subgroup 1				
1	Performance Tests	Per Table VII	Tests 1-12 of Table VII	13 (0)
2	Mechanical Shock	TM 2002	A, Y1 direction, 500G	
3	Performance Tests	Per Table VII	Tests 1-8 of Table VII	
4	Vibration	TM 2026	Condition A, 20G, 20 Hz to 2000 Hz	
5	Performance Tests	Per Table VII	Tests 1-8 of Table VII	
6	Thermal Shock	TM 1011	Condition A, 0°C to 100°C, 20 cycles	
7	Seal	TM 1014	Method compatible with pigtailed module	
8	Performance Tests	Per Table VII	Tests 1-8 of Table VII	
9	High-Temp Storage	3.3.2.1 and Table 4-4 in Telcordia GR-468	+85°C, 2000 hrs	
10	Performance Tests	Per Table VII	Tests 1-8 of Table VII	3 (0)
11	Low-Temperature Storage	3.3.2.1 and Table 4-4 in Telcordia GR-468	-40°C, 72 hours	
12	Performance Tests	Per Table VII	Tests 1-8 Table VII	
13	Temperature Cycling	GR-468, Table 4-4	Condition C, 100 cycles per Table 4-4 in Telcordia GR-468, -45°C to +85°C	
14	Performance Tests	Per Table VII	Tests 1-12 of Table VII	
15	Fiber Pull	Telcordia GR-468	1 kg	
Subgroup 2				
1	Solderability	TM 2003	Steam aging not required	3 (0)
2	Metal Package Isolation	RIO defined	600 VDC, 100nA maximum	
3	Lead Integrity	TM 2004 - B2	B2 lead fatigue	
4	DPA, including PIND, RGA, Wire Bond Strength and Die Shear	MIL-STD-1580	Performed by JPL Permissible to use samples used for Solderability, Package Isolation and Lead Integrity	
Subgroup 3				
1	Accelerated Aging	Table 5-1 in Telcordia GR-468	-40°C to +85°C	5 (0)
	Accelerated Module Life Test via Temperature Cycling		Continue Temperature Cycling tests (Subgroup 1, step 12) using devices that have completed Subgroup 1 testing to accumulate a total of 500 cycles.	
2	Performance Tests	Per Table VII test 1-12	Perform Tests 1-8 at the end of every additional 100 cycles, and Tests 1-12 at the end of 500 cycles.	
3	Accelerated Aging Tests via High Temperature Storage (Operation?)	Table 5-1 in Telcordia GR-468	+85°C, Continue High Temperature Storage Test (Subgroup 1, step 8) using devices that have completed Subgroup 1 testing to accumulate a total of 5000 hrs	
4	Performance Tests	Per Table VII test 1-12	Perform Tests 1-8 at the end of every 1000 hrs and Tests 1-12 after the 5000hrs.	

Qualification Process for AOM



Current Qualification Process (2/2)

- Different process used for passive devices
 - Different performance parameters and different reliability parameters





In closing

- Photonics market is a growing market, in some estimate it is expected to be over \$900 billions by 2024.
- Space application is a portion of this growth with its unique need and requirement.
- More photonics parts are being used or considered for space application due to its benefit, small mass, small size and low power
- Need to develop guidelines and methodology on how to qualify photonics devices for space application
- Need to have a good understand of failure modes of photonics devices
- Goddard has done some great work in this area, and ESA has been also working on this area as well.



Strategy for Qualification

- General strategy- Test according to Mil-STD and Telcordia
- Standard tests are generally not suited for the photonics devices
- Some considerations and constraints
- Cost reduction
 - Smaller number of devices per test groups
 - Reduction in the characterization parameters at each steps
- Small procurement volume
 - Not very attractive for COTS manufacturers
- Reliability and failure data
 - Development of photonic devices are moving fast and not enough time to have complete reliability and failure data for FM
- Space environments, vacuum, hermeticity, radiation, temperature range



Recommendations

- Establish a collaboration with other NASA centers, universities , industries and other institutions
- Prioritize parts that are being considered for near term missions
- Develop methodology for evaluation and space qualification of the photonics devices
- Develop guideline on how to bring photonic devices from TRL1 to TRL6



Thank You